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Improving Water-Quality through Real-Time, Continuous Monitoring

An innovative research tool with extensive application potential

Figure 1. Real-time, continuous water-quality monitor. This particular unit is deployed using a buoy system

Overview

An approach is described for monitoring water-quality continuously, and for developing surrogate regression equations to predict concentrations of other water-quality constituents. Although the approach described below is for estimating suspended sediment concentrations using turbidity as a surrogate, turbidity can theoretically be used to predict any particulate or sediment-associated water-quality constituent (such as bacteria, total phosphorus, and mercury).

Introduction

In most streams, the majority of suspended sediments are transported during storm-flow periods (Wolman and Miller, 1960), the very time when the fewest data are generally collected. These sediments (and sediment-associated contaminants) can degrade the quality of receiving waters, and damage the downstream ecosystem. Accurately estimating the suspended sediment concentrations and loads that are being delivered to streams and rivers remains an elusive goal.

Although manual sampling of suspended sediment concentrations will produce an accurate series of point-in-time measurements, robust extrapolation to unmeasured periods (especially high-flow periods) has proven difficult. Sediment concentrations typically have been estimated using regression relations between individual sediment sample concentrations and associated discharge values (for example, the USGS ESTIMATOR model); however, suspended sediment transport during storm events is extremely variable and it is often difficult to relate a unique sediment concentration to a given stream discharge. In one recent study, Christensen and others (2002) identified that only 50% of their study stations actually had significant correlations between suspended sediment concentrations and discharge.

Furthermore, studies that employ manual water-quality sampling will always suffer from numerous inherent challenges including:

- A relatively limited number of samples must be used to develop meaningful interpretations.
- The delay between sample collection and the reporting of laboratory results, especially when violations of a water-quality standard and public health are considered.
- Detailed understanding of in-stream variability (diurnal patterns, for example) is never developed.
- The time and cost associated with collecting representative water-quality samples can be considerable.
- Sampling designs for loading studies (which usually require targeted storm-runoff sampling), conflict with sampling designs for trend analyses (which typically require fixed-frequency sampling).

Given these limitations, innovative sampling approaches for generating detailed records of suspended sediment concentrations (and other parameters of interest) are needed.

One promising new technology for improved suspended sediment determination involves the continuous monitoring of turbidity as a surrogate for suspended sediment concentrations and other water-quality constituents. Turbidity measurements are typically well correlated to suspended sediment concentrations because turbidity represents a measure of water clarity and suspended sediments directly influence this clarity. Although this methodology is being piloted in Kansas, California, and Georgia, it has not been used in Region III.

Objectives

To initiate a continuous water-quality monitoring pilot study in Region III, and to demonstrate the utility of this approach for answering fundamental applied questions that are of interest to both State and Federal Agencies.

Approach

The estimation of sediment concentrations from turbidity data is completely analogous to the standard methods for developing continuous discharge records, in which stream stage (water level) is recorded continuously and a rating curve is developed based on a correlation between stage and discharge (Figure 2). Instead of developing a stage-discharge correlation to calculate continuous discharge, this methodology will develop turbidity-sediment correlations to calculate continuous suspended sediment concentrations and loadings. Continuous turbidity monitoring to predict suspended sediment concentrations appears to provide significantly more detailed and more accurate information than the classical approach that relies on correlations between discharge and limited sediment sampling.

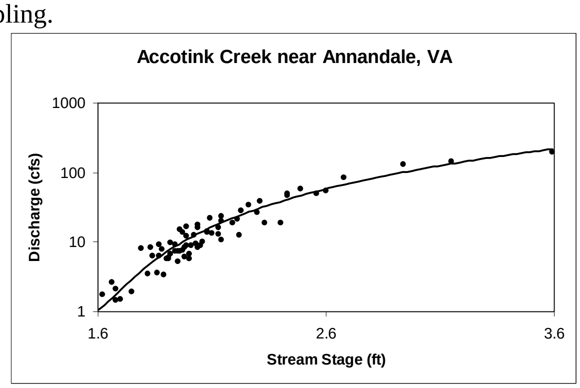

Figure 2. Example of a stream rating curve.

The methodology for this approach includes:

1. Deploy a continuously recording turbidity meter in a stream or river section with an existing stream gage.
2. The instrumentation is connected to telemetry equipment that communicates the sensor data back to a central office. In the office, the data are reviewed and served on the internet; the data can be used in “real time”.
3. During the initial phase of the study, manual samples are collected over a large range of turbidity conditions and analyzed for suspended sediment concentrations and any other target analytes.
4. Site-specific regression equations are developed to relate turbidity values and suspended sediment concentrations.
5. The regression equations are used to estimate continuous suspended sediment concentrations from the continuous turbidity data. Additionally, concentrations of other constituents, such as bacteria, may be estimated as well (Figure 3). Using the unexplained variance from the regression equation, uncertainty in the suspended sediment estimates can be quantified.

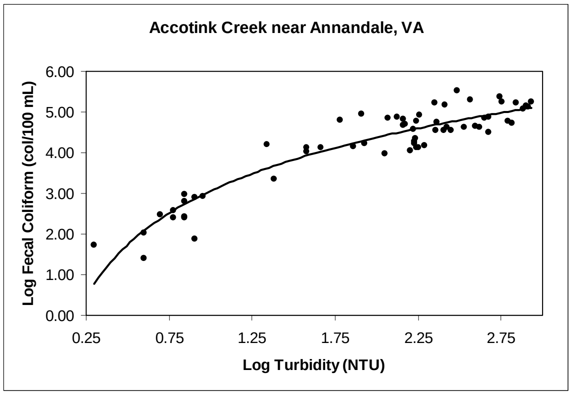

Figure 3. Relation between turbidity and fecal coliform concentrations.

Applications

Application of this surrogate technology should demonstrate an improved method for generating a continuous record of suspended sediment concentrations and numerous other constituents. This continuous surrogate approach has been initiated as a 1-year study on the James and Rappahannock Rivers in Virginia. Preliminary results are extremely encouraging and indicate that this surrogate methodology offers a powerful approach for improved water-quality data. For example, the turbidity data have already demonstrated the expected disconnect between discharge and sediment transport during storm events (Figure 4).

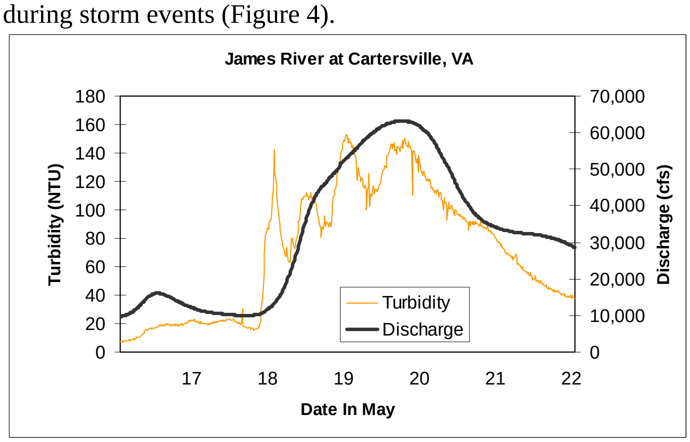

Figure 4. Continuous turbidity data during a James River runoff event. A disconnect is observed between flow and turbidity.

A number of applications exist for this innovative technology:

- After developing estimates of suspended sediment concentrations, bacterial concentrations, or other target analytes, these estimates can be coupled with discharge data to calculate continuous loadings for study streams.
- Continuous loading data will be useful in the development of TMDLs and other modeling activities; these continuous data will be an invaluable source of information for watershed modelers. For example, in the current pilot study, calculated sediment loadings will be compared to sediment load estimates from other existing methods (like ESTIMATOR); differences between methods will be documented and evaluated.
- Real-time display of continuous data on the web should assist decision makers in the protection of human health (availability of real-time data on beach bacteria levels, for instance). These real-time data should also generate significant public interest in current water quality.
- In addition to turbidity measurements, the field-deployed monitoring equipment also will contain sensors to continuously monitor specific conductance, pH, water temperature, and possibly dissolved oxygen and chlorophyll a. These additional parameters provide for a more detailed understanding of the water-quality in a given environment, and may even function as other useful surrogates (Hyer and Moyer, 2003).
- Once the surrogate regression equations are developed, sampling requirements are sharply reduced; in the long term, this approach should reduce the cost of water-quality monitoring.
- This technology and approach can be applied at any scale – from large watersheds (the James River) to small BMPs (like an individual construction site).
- Continuous water-quality monitoring should provide a mechanism for detecting changes in water quality that are related to intensive BMP implementation. The continuous turbidity data and turbidity-sediment regression relationships should provide improved capability for selecting sediment-reduction strategies, assessing trends in water quality, evaluating progress in achieving sediment-reduction goals, and determining sediment reductions resulting from implementation activities.

References

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